Proceedings of the XIIth International Congress for Electron Microscopy

SURFACE MAGNETIC MICROSTRUCTURAL ANALYSIS USING SCANNING ELECTRON MICROSCOPY WITH POLARIZATION ANALYSIS (SEMPA)

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High resolution imaging of magnetic microstructure has important ramifications for both fundamental studies of magnetism and the technology surrounding the magnetic recording industry. In SEMPA[1,2,3], a focused beam of electrons excites secondary electrons on a ferromagnet's surface. The secondaries leave the solid with an electron spin polarization which is characteristic of the net spin density in the ferromagnet. This is related directly to the sample magnetization. By scanning the beam and analyzing the secondary electron spin polarization at each point, a magnetization map of the ferromagnet's surface is generated.

As SEMPA is a surface sensitive, magnetic microstructural analysis technique, the environment local to the specimen must be ultra-high vacuum. A schematic of our SEMPA instrument is shown in figure 1. The probe forming electron optical column of a SEMPA system must produce small probes with high currents (> 1 nA) at long working distances (> 10 mm). The SEMPA system may be equipped with a single[2,3], or multiple spin detectors[1] as in figure 1. Two detectors are used for the acquisition of all three orthogonal components of the polarization vector signal. The inefficiency of all polarimeters makes SEMPA time consuming when compared to conventional SEM. The polarized secondary electrons must be extracted efficiently without introducing any deleterious effects into the focused incident electron beam. This imposes limits on incident beam energies and extraction voltages for the transport optics. Additionally, the transport optics must map the scanned spot of the secondary electrons produced under the incident rastered beam, to a (stationary) position on the spin detector such that undesirable instrumental asymmetries are not introduced[1].

In Figure 2, SEMPA images are shown for an Fe crystal (whisker). The horizontal and vertical components of the magnetization are shown in Figs. 2a and 2b respectively. The characteristic diamond domain found in Fe and the zig-zag domain wall along the side of the whisker are visible. These two images are exactly registered as they were acquired simultaneously together with the SEM intensity image. Here, white (black) corresponds to magnetization along the positive (negative) directions.

Domain walls[4,5] lie between regions of opposite magnetization, between the white and black domains shown in Fig. 2b. Although the size of domain walls may vary greatly, in general they are of submicron dimensions. The domain wall profiles shown in Fig. 3 show the horizontal (x) and vertical (y) component of the magnetization for a surface domain wall in a 0.24 μm thick permalloy film. The measurements are given by solid points and the theory is shown by solid lines. Two theoretical curves result from convolving the theoretical profile with the two limiting experimental probe profiles for the measurement. The agreement illustrates that SEMPA can be used for testing micromagnetic models[6] at high spatial resolution.

References

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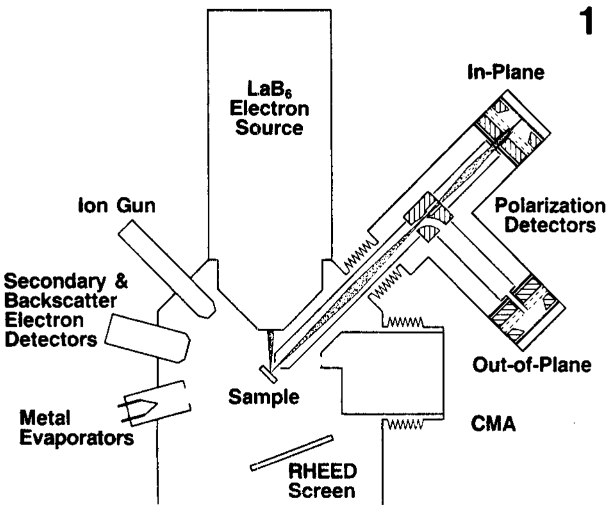
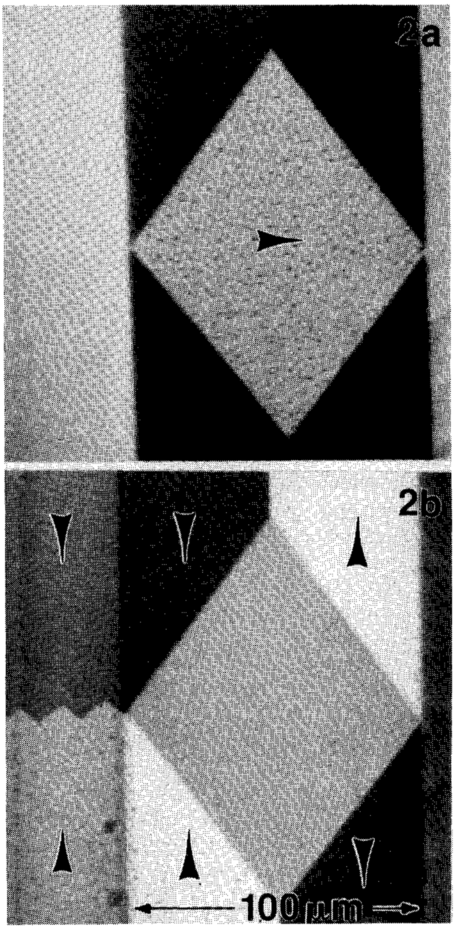
6. This work was supported in part by the Office of Naval Research.





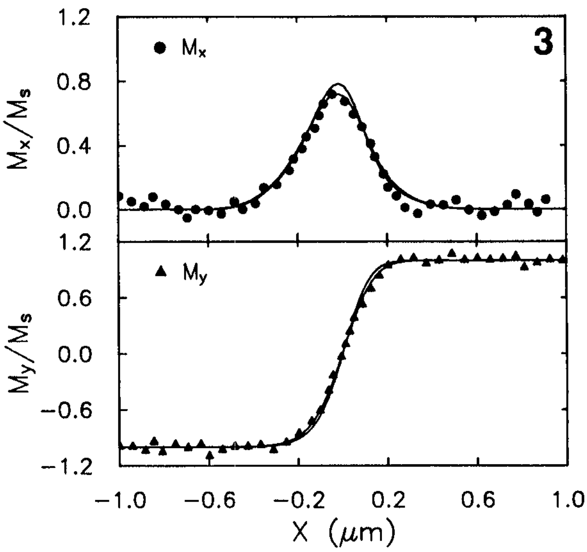


Fig. 1 : Schematic of the NIST LaB_6 source, three axis detector SEMPA instrument.
Fig. 2 : (a) Horizontal and (b) vertical component of the magnetization in a single crystal of Fe. White (black) corresponds to magnetization in the positive (negative) directions.
Fig. 3 : Domain wall magnetization profiles for a 0.24 μm thick permalloy film. Measurements are solid points and theory convoluted with limiting measured probes is plotted with solid lines.